

# The principles of the milling equipment improvement

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**Abstract.** The article presents the results of the investigations of evaluation of the effectiveness of implementation of the equalized functionality mineral-processing equipment, using criteria for the specific action, calculated based on the simple indexes aggregation, which describes resource, spending on achievement the end result unit of the functional event (multi-criteria estimation). As a major specific action criterion for the estimation of milling equipment we used the criterion, which takes into account expenditure of energy and time. The need to generate more production-friendly constructions became a reason for creation of the recommendations for further improvement of the mineral-processing equipment. These recommendations based on selection of the milling process variables, which has the greatest impact on the qualitative and quantitative indicators of mineral processing, and on analysis of possible changes of chosen parameters to decrease in the specific actions. In conformity with the practical implementation of these development principles, have been developed the new methods of milling and construction arrangement of the mills, based on the implementation of the specific action criteria, which ensure the positive effect, resulting from the decrease in unit costs during the manufacturing of saleable products from the mineral raw materials.

## 1 Introduction

For modern concentrating machines is an evidence the trend to expansion of functional possibilities due to rising of operational loads under metal intensity decrement, enhancing productivity and the reduction of the refinement time, improvement of the accuracy, efficiency and reliability [1]. The investigations, which took place in the Mining college of NUST MISIS (Moscow), had proved the possibility to estimate the evaluation of an equipment with a help of an versatility indicator, calculated on the base of aggregation of the simple measurements, characterizing the resources spends on achieving a unit of the final result of work [2].

The complex indexes, calculated on the basis of aggregation of simple measurements, are actually the lows of least action, which was generated by Maupertuis, Euler, Lagrange, Hamilton and other scientists [3] and which were used by modern scientist as criteria of

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specific actions for optimization of different mechanical systems (multi-criteria estimation) [4]. Criteria of specific actions assesses the degree of sophistication of analyzed systems, elucidate the parameters under which the system is close to optimal [5].

## 2 Objects and methods of research

The multi criteria estimation is one of the most objective method of benchmark program of equipment, but it does not exclude or replace the existing methods and criteria, but only supplements them. The most appropriate use of this method is in assessing the effectiveness of the new equipment [6]. For example, when creating new types of such mineral-processing equipment as screens it is necessary to quantify contamination materials after processing and motion speed of the material over the screen; when creating new types of mills – to quantify the specific energy costs. Additionally, in both cases it is necessary to determine the time of obtaining the single mass of the base product of the refining. As a characteristic criterion of specific action for appraisal of grinding equipment is used the criterion, which takes into account mechanical energy and time input.

$$J_{e-t} = P_m \cdot t_s^2, \quad (1)$$

where  $P_m$  - mean power, used for grinding, kW;  
 $t_s$  - refining time to obtain the single mass of the base product, hours.

For comparison of different types of mills with different producing capacity, it is necessary to take into account their specific gravity, that is the mass, referred to the feed capacity. In this case the summarized criterion of specific action is:

$$J_{e-t-m} = \sum P_m \cdot t_a^2 \cdot \sum M_i, \quad (2)$$

where  $\sum P_m$  - summarized intake power of processing equipment, kW;

$t_s$  - processing flow time while obtaining the single mass of the base product, hours;  
 $\sum M_i$  - specific total mass of the in-process equipment, t (t/h).

Another feature of multi-criteria estimation of equipment is the possibility of developing of the new constructive decisions, that can in best way realize the specific task of waste treatment in these conditions [6].

Often such a choice can be made using existing constructions of grinders and mills, involved in the main processing lines. However, for certain processing conditions the common designs do not always meet the requirements (for example the separation of wastes of natural moisture without drying, etc.). In this case, it is required either to refine the known designs, or to develop fundamentally new ones.

The need to create more technological designs became a reason for developing the further improvement principles of the mineral-processing equipment. In solving the practical problems of implementing pointed principles under different operating conditions has been designed new engineering solutions (protected by copyright certificates and patents), which provide the positive effect by reducing unit coast of producing different market products [6-8].

## 3 Results and discussions

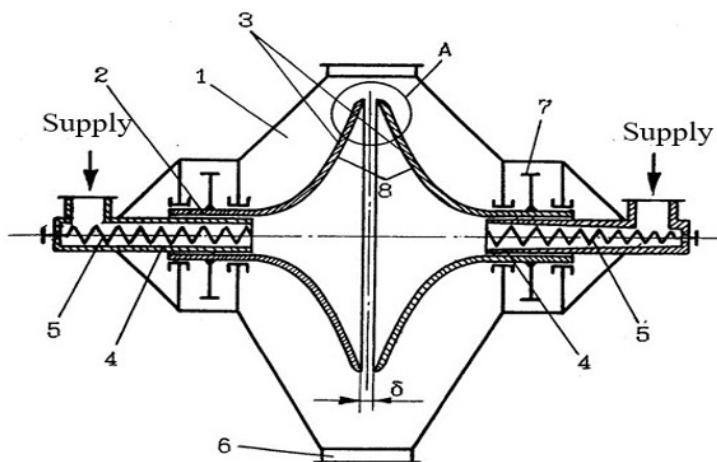
The guidelines to improve the grinding equipment are organized around the following main points:

- Selection of the grinding process, which has the greatest impact on the qualitative and quantitative processing indicators;
- The analysis of the selected parameter's change directions with the aim of modifying indicators to reduce specific actions.

The practical implementation of the updating principals of grinding process has been used in such scientific works as vibratory mill (according author's certificate (a.c.) № 893259), vibratory mill (according a.c.№1802434), planetary mill (according a.c. №1431834), centrifugal mill (according the patent №2108865) with the way of milling (according the patent № 2498857), sizing separator (according the patent № 2531438) and others.

For example, the centrifugal mill (according the patent №2108865) has been developed with the aim to improve the scrubbing efficiency effect through increased impact rate of material particles while grinding (Figure 1). The mill consist of a milling unit in the form of enclosed (1) coaxial rotors (3) on shafts (2), rotating the other way round. The material loading through the nozzles (4), inside of which are feeding screws (5). The discharge devise (6) has a form of an outlet fitting on the underside of the housing (1). The shafts (2) are rotated by the drive unit, for example by gear-wheels (7). The row material is displaced by feeding screws (5) from both sides along the nozzles (4) to the rotors' working space, where the centrifugal forces accelerates it at the beginning slowly and then faster and faster up to high velocities. The acceleration characteristic depends on the form of the rotors' working surface (3), which in its turn depends on the row material sizing. After the separation of particles from rotors (3) occurs the flows encounter, identified by the oblique impact and the particles rub against each other, which leads to intense self-grinding of the material.

This mill construction provides the most efficient milling with minimum energy consumption and reduces by 30% the value of the  $J_{c-t-m}$  criterion in compare with existing centrifugal mills used for these conditions.



**Fig. 1.** Construction of the centrifugal mill

Some of designs have been implemented in production. For example, the pilot and field testing of the inclined vibratory mill (according author's certificate №1802434) in the wet milling production line of lime dust in the Khomyakovskiy quarry (Tula, Russia) has generated an increase of the marketable product of the grinding-sorting factory [6].

The results of analysis and based on them developed principles of the mills upgrading are presented in the Table 1.

**Table 1.** Principles of the mills upgrading.

<b>Grinding process parameter</b>	<b>Direction change of the parameter variations</b>	<b>Principals of the technical improvement of the constructions (specified engineering solutions)</b>	<b>Positive result</b>
1	2	3	4
Value of overground particles	Reduce	Distribution of the grinding bodies of various sizes along the curved grinding chamber of the vibration mill [9]	Improved grinding quality
Stress rate while grinding	Reduce	To fulfill the working surface of the crushing rolls (of the roller mill), which forms V-slots, with the like-sign curvature [10]	Increase the degree of grinding and the grinding energy consumption reduction
Collision frequency of the mill charge and balls	Increase	To provide the independent mode of vibration for the grinding chamber's half shells of the vibration mills [11]	Increase the degree of grinding
The number of collisions of coarse particles with coarse balls	Increase	To ensure continuous size classification of the grinding balls in the grinding chambers of vibrating mills [12]	Increase in efficiency
Acceleration rate of the disintegrated media	Increase	To create rotational asymmetric movements of the grinding bodies in the contrary directions over different locations in the working chamber of a vibrating mill [13]	Increase in the degree of grinding
Value of overground particles	Reduce	Provide the sectional continuous vacuum extraction of the mill products from inclined grinding chambers of the vibrating mill [14]	Increase in productivity and quality of grinding
Amount of collision of particles	Increase	Provide a multiple cycles regime of grinding in the grinding drums of a planetary mill [15]	Increase the degree of grinding

<b>Grinding process parameter</b>	<b>Direction change of the parameter variations</b>	<b>Principals of the technical improvement of the constructions (specified engineering solutions)</b>	<b>Positive result</b>
Velocity of collision of the materials particles	Increase	Create the optimal design of an acceleration disk of the centrifugal mill [16]	Reduction of energy consumption for grinding
Quantity of overground particles	Reduce	Create an ordered supply of grinding balls of different diameters into a working chamber with perforated curved bottom [17]	Improve grinding quality and reduce energy consumption for grinding
The integral action intensity on the material	Increase	Provide the possibility of creation both normal and shearing (tangential) stresses in the mill feed [18]	Improving the productivity and energy efficiency of the grinding process

## 4 Conclusions

1. It is possible to develop the quantity and quality characteristics of the grinding process using the specific action criteria, that assess the level of sophistication of the systems to be studied.
2. The principals of the grinding equipment upgrade are based on the choice of the grinding parameter, which has the greatest impact on the qualitative and quantitative indicators of mineral processing, and the analysis of changes for chosen parameter to improve the indicators by reducing specific action.
3. The application of the specific action criteria allowed to develop the milling methods and the construction diagrams of mills, that provided a positive effect by reducing the unit costs of various saleable products from mineral raw materials.

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